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Early Developmental Differences among Five Lodgepole Pine Provenances Planted on a Subalpine Site in Montana

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ABSTRACT

Lodgepole pine seedlings from British Columbia, Washington, Idaho, and Utah were planted along with a local provenance on a high-elevation site in south-central Montana. After 7 years, survival rates were similar, but growth rankings among provenances have changed. Trees must grow above the winter snow level for a few more years before the performance of each provenance can be clearly characterized.

KEYWORDS: provenances, seedlings, growth patterns, planting, lodgepole pine, *Pinus contorta*

Lodgepole pine (*Pinus contorta* var. *latifolia*) is often considered in the management of sites where its successional role (Pfister and Daubenmire 1975) is either dominant seral, persistent, or climax. Although lodgepole is the climax species on a relatively small area, it is a dominant seral or a persistent species over vast areas near and east of the Continental Divide in the United States and Canada. Here, stands are usually regenerated by clearcutting and artificial regeneration is sometimes required when natural regeneration fails. Natural regeneration sometimes fails when site scarification has been inadequate or logging and silvicultural activities have not been properly coordinated with the level of cone serotiny of the harvested stand.

When lodgepole pine must be artificially regenerated, a local seed source is commonly used. Perry's (1974) greenhouse experiments, however, have shown that 1-year-old lodgepole pine seedlings from Idaho, Washington, and British Columbia were taller and heavier than those from high-elevation sources in Montana and Utah, although little difference in response to day length and temperature differences was noted among the sources. And in British Columbia, studies of 144 provenances (Illingworth 1975) planted at coastal versus inland locations showed that growth was not correlated with proximity of seed source, but that early height growth and frost resistance differed among provenances. These studies suggested that geographical differences in productivity of stands might have a genetic component and that seedlings might be grown successfully in continental climes from seed gathered from a considerable distance if sufficiently adapted to cold.

Subsequent provenance studies have clearly shown that adaptation in lodgepole pine is closely related to environmental variables (Critchfield 1980; Rehfeldt and Wykoff 1981). Rehfeldt and Wykoff found that heritability for growth among 30 lodgepole pine populations of Idaho and Montana was expressed through adaptation of shoot elongation to the length of the growing season rather than temperatures alone of the widely different elevations tested. Correspondence of variation in shoot elongation with variation in freezing tolerance was interpreted as evidence that height growth of lodgepole pine seed sources is coordinated with cold acclimation through adaptation to the length of the growing season. More recently, Rehfeldt (1983) has qualified and quantified the adaptation potential of 28 northern Idaho lodgepole pine populations for cold hardiness and growth potential and has synthesized these negatively correlated traits into guidelines for determining seed transfer intervals for northern Idaho lodgepole pine populations.

Perry's tests—as well as the mild-environment tests of Illingworth and Rehfeldt/Wykoff—measured the innate growth potential of various lodgepole pine seed sources. On the basis of the greenhouse results of Perry and the availability of sibling seedlings from the same parent trees used by Perry, we decided to measure performance on a severe site: actual growth expression of Perry's five seed sources in a high-elevation Montana environment. This paper reports 7-year results of the study. Eventually, differences in growth patterns will be quantified in terms of timber productivity.

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METHODS

Seeds were collected from 10 parent trees in each of five widely separated stands in Utah, Montana, Idaho, Washington, and British Columbia. Locations, latitudes, elevations, and site indexes of the stands are shown in table 1. Stands were selected from the *Abies lasiocarpa/Pachistima myrsinites* habitat type or its ecological equivalent (Daubenmire and Daubenmire 1968) to represent, as much as possible, reasonably uniform growing conditions for lodgepole pine (Perry 1974).

Seeds were planted in 1972 at Lucky Peak Nursery, near Boise, Idaho, and lifted as 3-0 stock in the spring of 1975 for transplanting on the study site. The study area is located near Rat Lake—Squaw Creek drainage, Gallatin National Forest, Mont.—in a clearcut area harvested in 1970. Lodgepole pine was the major species in the overstory, with a small proportion of Engelmann spruce (*Picea engelmannii*) (Parry) distributed throughout the stand. Site index for lodgepole pine is 60 to 70 ft (18 to 21 m) at 100 years, and elevation is about 6,600 ft (2 000 m) above sea level.

The soil in the study area is a silt loam, developed to 18+ inches (46+ cm). The study area lies across a gentle draw midway up a gentle, north-facing slope. The site is quite moist into July in most years. No weather data are available for the immediate study area, but total annual precipitation recorded at the Squaw Creek Ranger Station, 4 mi (6.4 km) distant, averages 30 inches (76 cm). The ecological habitat type (Pfister and others 1977) is *Abies lasiocarpa/Linnaea borealis*. Prominent understory species at the time of harvest were *Linnaea borealis*, *Vaccinium caespitosum*, and *Calamagrostis canadensis*.

Seedlings were lifted from the nursery as 3-0 bareroot stock before spring growth began in 1975, bundled by parent tree identity, and placed in cold storage until the planting site was free of snow.

Two hundred and eighty-four seedling representing from 4 to 10 offspring of each parent tree were planted on June 9-10, 1975, in 13 rows of a 0.75-acre (0.3-ha) plot. Trees were spaced 10 ft (3 m) apart in the rows, and rows were spaced 10 ft (3 m) apart. Planting spots were grouped by parent tree—that is, all seedlings from a given parent tree were planted in consecutive planting spots of a row, but the row-location of a group of seedlings from a single parent tree in relation to those from another parent was random. It would have been desirable to completely randomize the experiment to the individual tree level; however, randomization of individual seedlings was foregone because it would have required increased handling and might have caused increased mortality and confounded survival and growth results.

Planted seedlings were staked and identified with tags showing the seed source, parent tree, and individual tree number of each seedling.

Mortality was recorded, and total height and annual height growth were measured in centimeters—in 1976, 1978, 1979, and 1982. Crown width, in centimeters, was added to the measurements in 1982.

Data were analyzed for differences in survival, crown width, total height, and periodic and annual height growth. The chi-square test was used to evaluate differences in survival rates. Because mortality differed significantly in the 1975-76 establishment period and could confound growth means, growth measurements for 1976 were not used to test growth differences among the provenances—with the exception of total tree height in 1976, which was used as a covariate in testing provenance differences in height growth after 1976. Crown width of the trees was also found to covary with their heights; therefore, height of trees in 1982 was used as a covariate in the analysis of variance of 1982 crown widths among provenances.

Table 1.—Location and site characteristics of stands providing seed for the provenance study

Stand	Location	Elevation		Habitat type	Site index (Alexander 1966)
		Feet	*(Meters)*		
Washington	Sherman Pass, Colville N.F., lat. 48°36′ N	5,250	(1 600)	Abies lasiocarpa - Pachistima myrsinites (Daubenmire and Daubenmire 1968)	90
Montana	Butte Meadows, Gallatin N.F., lat. 45°26′ N	7,220	(2 200)	Abies lasiocarpa - Galium triflorum (Pfister and others 1977)	80
Utah	Gilbert Creek, Wasatch N.F., lat. 40°54′ N	8,200-11,480	(2 500-3 500)	Abies lasiocarpa/Berberis repens and A. lasiocarpa/Vaccinium scoparium (Pfister 1972)	45
Idaho	Little Slate Creek, Nezperce N.F., lat. 45°40′ N	5,100	(1 550)	Abies grandis - Xerophyllum tenax (Steele and others 1981)	90
British Columbia	Cariboo Land District, lat. 53°25′ N	2,300	(700)	Unknown, but probably Abies lasiocarpa -Clintonia uniflora (Daubenmire and Daubenmire 1968)	100

RESULTS

Survival

Survival rates of the provenances ranged from 77 to 90 percent in the first year and 74 to 88 percent in the seventh year after planting (table 2)— indicating that most of the mortality to date occurred in the first year. The chi-square value for differences in survival rate among the five provenances in 1976 was 9.97, while the appropriate table value of chi-square at the 0.05 level is 9.49; thus, we conclude that the differences among the survival rates of the provenances in the first year were significant at the 0.05 level. This is primarily due to the lower initial survival rate of the Idaho seedlings. The corresponding chi-square test of percentage of survival in 1982 ($\chi^2 = 7.87$), however, indicates that differences in survival among the provenances after 7 years are no longer significant.

Growth

Means and standard deviations of total heights, annual leader growth, and crown widths of trees are summarized in table 3 for provenances at each year of measurement. Results of covariance analysis of the four growth expressions used as response variables are discussed below.

Table 2.—Number of trees planted and percentage of trees surviving in 1976 and 1982, by provenance

Provenance	Trees planted 1975	Percent surviving	
		1976	1982
Utah	63	90	83
Montana	51	90	88
Washington	46	87	78
Idaho	43	77	74
British Columbia	81	88	84
Total and percentage means	284	86	81

Table 3.—Means and standard deviations (in parentheses) of heights, terminal leader lengths, and crown widths—by provenance and year of measurement

Provenance	Year	Total height	Terminal leader length	Crown width
		Centimeters		
Utah	1976	18.9 (9.2)	5.4 (3.2)	—
	1978	34.5 (11.4)	10.9 (4.6)	—
	1979	45.1 (15.3)	12.1 (5.7)	—
	1982	87.5 (27.5)	19.2 (7.7)	46.1 (18.2)
Montana	1976	18.7 (5.3)	5.7 (3.2)	—
	1978	36.8 (12.8)	11.0 (5.0)	—
	1979	48.4 (17.5)	12.9 (6.1)	—
	1982	93.8 (31.1)	21.5 (7.7)	53.3 (18.8)
Washington	1976	23.0 (7.4)	6.9 (4.8)	—
	1978	43.6 (15.2)	13.4 (5.2)	—
	1979	56.6 (19.9)	13.8 (5.7)	—
	1982	110.8 (38.9)	20.8 (10.5)	53.6 (18.6)
Idaho	1976	21.3 (8.3)	6.5 (4.0)	—
	1978	43.7 (15.9)	15.5 (5.9)	—
	1979	60.2 (19.6)	15.9 (5.6)	—
	1982	119.2 (35.8)	24.4 (9.8)	62.2 (19.0)
British Columbia	1976	27.2 (7.6)	7.8 (4.6)	—
	1978	56.0 (19.0)	17.6 (6.9)	—
	1979	72.5 (24.2)	18.3 (7.3)	—
	1982	133.4 (44.4)	24.4 (10.2)	69.7 (23.4)

CROWN WIDTH

Crown width in 1982 differed significantly (P = 0.015) among the provenances according to the overall F-test of mean crown widths adjusted for mean heights of the provenances in 1982. T-tests of all provenance comparisons (table 4), taken two at a time, revealed that 1982 crown widths, adjusted to a common height, were significantly greater (0.05 level) for Montana trees than those of Utah and Washington, while crown widths of trees from British Columbia were significantly greater than Washington trees. Crown width differences between the other provenances were not significant at the 0.05 level.

TOTAL HEIGHT

Total 1982 height differed significantly (P = 0.009) among provenances when means were adjusted for 1976 heights. Paired t-tests of adjusted total 1982 height means (table 4) for the 10 provenance combinations showed that Idaho and British Columbia trees were significantly greater (P = 0.05) than those of Montana and Utah. Adjusted heights of Washington trees were intermediate to the other provenances, but not significantly different from them. The 1982 heights were adjusted because British Columbia, Washington, and Idaho seedlings, although not measured, were observed to be taller than those of the other provenances at the time of planting. This was the same pattern of differences observed by Perry (1974) on progeny of the same parents after 1 year in a greenhouse.

PERIODIC HEIGHT GROWTH

Periodic height growth, 1976-82, demonstrated the same pattern as total heights, differing significantly among provenances (P = 0.009) when growth means were adjusted for heights in 1976. T-tests of the adjusted mean differences of all combinations of provenance comparisons, taken two at a time, showed that 6-year height growth of Idaho and British Columbia trees was significantly greater (0.05 level) than those of Utah and Montana (table 4). Washington trees were intermediate to, but not significantly different from, the other provenances.

CURRENT HEIGHT GROWTH

No significant statistical differences in current (1982) annual height growth were detected among provenances when means were adjusted for tree heights in 1976. Although the overall F-test of the adjusted provenance means of 1982 height growth (table 4) did not allow rejection of the null hypothesis, lack of significance on this test can be due to relatively large differences in the mean values of the covariate among the provenances (Snedecor and Cochran 1967), such that only very large provenance differences could be detected. The Newman-Keuls sequential test of ranked adjusted means was used to test against this possibility; however, the greatest difference in adjusted provenance means (Idaho versus Washington) was still not significant at the 0.05 level.

DISCUSSION

Early differences in survival and height growth, among the provenances studied here, appear to be changing. Survival rates have nearly equalized and total height-growth rankings have shifted from their earlier pattern. Remeasurement of the study 5 to 10 years hence will provide a better indication on whether differences will disappear or continue to change.

At this point, we believe that differences among the provenances will continue to develop and will be different in pattern than shown to date. We base this opinion on two facts: (1) the local (Montana) seed source has the highest crown width/height ratio at present, and has risen to second place in current annual adjusted height growth, compared to its fifth place ranking in total height 6 years earlier, and (2) seedlings and saplings have been covered and protected by deep winter snows, therefore, climate has yet to fully express its potentially discriminating effect on survival and growth. In the next 5 to 10 years, most of the trees will grow above the snow level and differences in provenance growth and survival then could indicate unsuitability of some provenances for planting on high elevation sites in Montana.

Table 4.—Covariance-adjusted provenance means of four growth expressions

Provenance	Mean 1982 crown width adjusted for mean 1982 height		Mean total 1982 height adjusted for mean 1976 height		Mean periodic height growth 1976-82, adjusted for 1976 height		Mean 1982 height increment adjusted for 1976 height.	
	Inches	*(cm)*	*Inches*	*(cm)*	*Inches*	*(cm)*	*Inches*	*(cm)*
British Columbia	23.1	(58.6) ab[1]	46.5	(118.0) a	38.1	(96.8) a	8.7	(22.2) a
Idaho	22.8	(57.8) abc	47.8	(121.4) a	39.1	(99.2) a	9.8	(24.8) a
Washington	20.9	(53.2) c	42.2	(107.1) ab	33.4	(84.9) ab	8.0	(20.3) a
Montana	24.0	(61.0) a	40.9	(103.9) b	32.2	(81.7) b	9.0	(22.9) a
Utah	22.4	(56.8) bc	39.4	(100.1) b	30.1	(77.9) b	8.2	(20.7) a

[1] Adjusted provenance means not sharing a common letter within a column are significantly different at the 0.05 level for that growth expression.

CONCLUSIONS

1. Seedlings from all provenances have been able to survive for 7 years in this high-elevation Montana habitat, with no significant differences in survival rates among provenances over the past several years. Nevertheless, this situation might change in the next few years as all provenances grow above the winter snow level of the site, thereby exposing the trees to greater climatic extremes. At that time, the survival rates of trees from some seed sources could be significantly reduced.

2. Growth differences among provenances expressed in the 1-year greenhouse trials of Perry (1974) were duplicated in the first year of outplanting of siblings from the same parents on this high-elevation site. But, patterns of 1982 height growth, relative to growth over the 7-year period, indicate that the Idaho and Montana seed sources are gaining on provenances that earlier surpassed them. This is probably due to inherent tolerance of winter and early spring climatic extremes that are now coming into fuller expression as the trees grow toward and then protrude above the winter snow level. How this adaptation advantage translates to long-term performance, relative to the other seed sources, can only be determined by continued study.

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